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THE CERES S'COOL PROJECT: DEVELOPMENT AND OPERATIONAL PHASES

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1. INTRODUCTION

As part of NASA's Mission to Planet Earth, the first Clouds and the Earth's Radiant Energy System (CERES) instrument will be launched on the Tropical Rainfall Measuring Mission (TRMM) spacecraft from the Tanegashima launch site in Japan in November 1997. The instrument will measure the radiation budget - incoming and outgoing radiant energy - of the Earth. The major feature of interest is clouds, which play a very strong role in regulating our climate. CERES will identify clear and cloudy regions and determine cloud physical and microphysical properties using imager data from a companion instrument. Validation efforts for the remote sensing algorithms will be intensive.

As one component of the validation, the S'COOL (Students' Cloud Observations On-Line) project will involve school children around the globe in making ground truth measurements at the time of a CERES overpass. They will report cloud type, height, fraction, and opacity, as well as the local surface conditions. Their observations will be collected at the NASA Langley Distributed Active Archive Center (DAAC) and made available over the Internet for educational purposes as well as for use by the CERES Science Team in validation efforts. Pilot testing of the S'COOL project began in January 1997 with two local schools in Southeastern Virginia and one remote site in Montana. National testing in April 1997 involved 8 schools (grades 3 to high school) across the United States. Global testing will be carried out in October 1997. Details of the S'COOL project, which is mainly Internet-based, are being developed in each of these phases according to feedback received from participants. In 1998, when the CERES instrument is operational, a global observer network should be in place providing useful information to the scientists and learning opportunities to the students. Broad participation in the S'COOL project is planned, both to obtain data from a wide range of geographic areas, and to involve as many students as possible in learning about

clouds and atmospheric science.

This paper reports on the development phase of the S'COOL project, including the reaction of the teachers and students who have been involved. It describes the operational state of the S'COOL network, and identifies opportunities for additional participants.

2. DEVELOPMENT PHASE

The initial idea for the CERES S'COOL Project arose in December 1996 during a conversation with a 6th grade teacher, Mrs. Elinor Jones, from Gloucester, VA, who was visiting NASA Langley. She was interested in a simple, safe, and cheap experiment that she could have her students perform; and *the results of which could be sent to NASA*. She felt this connection to NASA - even if the results were never used - would be a great motivator to the students and would help them feel connected to the larger world. Given the importance of clouds to the Earth's climate, and the upcoming launch of a new NASA instrument -- CERES -- developing a cloud observer project seemed a natural idea. The decision was made to start working on such a project, with regular involvement from teachers and students to ensure it would be useful to them.

2.1 Phase 1a: Gloucester - Postal Interface

The first step was to test the concept with real students, to find out whether it had merit in the real world. A visit to Mrs. Jones' classroom was arranged. A NASA scientist (the first author) and a meteorologist (Walt Baskin of the Langley DAAC) drove up to Peasley Middle School on a Monday in January with overhead slides and cloud charts in hand. They explained the project to the students and gave them some training as observers. The perfectly clear weather gave them the opportunity to stress the importance of reporting clear skies in a cloud observer program. Cloud detection against the variable background of the Earth's surface is one of the biggest challenges in remote sensing from orbit.

The students continued to observe and report their results via postcard daily for the rest of the week. Comparisons were then made with Advanced Very High Resolution Radiometer (AVHRR) data from the National Oceanic and Atmospheric Administration's NOAA-14

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spacecraft as a surrogate for the yet-unlaunched CERES instrument. Of 4 parameters compared over 5 days, there were only two instances of disagreement:

- On Wednesday the students reported high cirrus clouds while the satellite saw ice clouds at 5.5 km altitude. Though clearly high cirrus clouds were present, the CERES data processing identifies these as mid-level clouds. This issue is unresolved.

- On Thursday the students reported mid-level stratocumulus clouds, while the satellite saw low altitude water clouds. It was later determined that the cloud chart the students had available mis-identified the height classification of stratocumulus. As a result, a consistent cloud chart is now sent to all participating classes.

A second visit to the classroom was made to report to the students on how their observations compared to the satellite results. At this time it was also determined that some of the temperature readings were in error because the thermometer was placed in the sun. The instructional materials were modified to avoid this problem in future measurements. The teacher reported that the week had gone very well and the students had been quite enthused. A decision was made to begin more extensive development of the project, including development of a catchy acronym and a logo.

2.2 Phase 1b: Big Timber - E-mail Interface

A test to assess the feasibility of an e-mail reporting system was performed by 6th grade students at Big Timber Grade School, Big Timber, MT, in March 1997. An 8 page write-up about the project was mailed to teacher Rolland Karlin beforehand. The e-mail interface worked very well. Satellite observations were available for only two of the days, and these pointed out two more issues for the comparison of surface- and satellite-based observations:

- On March 11 the students reported overcast low clouds while the satellite reported high clouds. Such disagreements are expected when vertically developed or multi-layer cloud systems are present. In such instances the S'COOL data are of potential use in validating the cloud base altitude estimated by the CERES algorithms.

- On March 12 the students reported mostly cloudy skies (50-95% cloud cover) while the spacecraft reported 100% cloudiness. This is an example of another difficult aspect of comparing surface and satellite observations. The difference in cloud amount is due to the difference in the areas considered. The area seen by the surface observer is a function of several things such as surface elevation, atmospheric haziness, cloud height, and whether the observer's view of the horizon is blocked by buildings or trees. The satellite observer must try and match the viewing area seen from the surface. In this case, the satellite area was probably too small and missed some clear sky seen from Big Timber.

This teacher also reported a positive experience: "The kids learned and it was fun. [...] the kids did most of it. They felt important."

2.3 Phase 1c: Poquoson - Internet Interface

A final test was performed in Phase 1 to evaluate an Internet report form. This test was performed by a 4th grade class at Poquoson Elementary School, Poquoson, VA. As part of a unit on clouds, a NASA meteorologist (the second author) visited this classroom to talk about clouds and weather in general and to introduce the S'COOL Project. The students made observations for a week and reported them via the Internet. This medium also worked very well.

The teacher, Carol Mitchell, reported: "It was a perfect addition to our Science weather unit and covered the S.O.L.'s [Standards of Learning] as well as spilling into other curriculum areas and getting the class out of the traditional classroom." These students wrote descriptions of the clouds they saw, in addition to just reporting dry facts. They also used maps, and they averaged estimates from all the students to get a more reliable value of cloud fraction. This is an excellent example of a creative classroom teacher leveraging a rather simple concept for the benefit of her students.

As a measure of student motivation, one student was overhead saying: "We have to do this ... NASA is depending on us." while donning rain gear to make an observation in less than ideal weather. A front page article reporting the students' involvement appeared in the local newspaper.

The results from this class were excellent, agreeing with the satellite data even for broken, multi-layered cloud systems.

2.4 Phase 2: National Testing

The lessons learned from Phase 1 were incorporated in the S'COOL website (Ref. 1) while contacts were developed for the next phase. Word of mouth through friends and relatives turned out to be a fruitful way to find interested teachers distributed widely across the country. This phase was intended to demonstrate that the project would work with little personal involvement from NASA researchers; and that we could find interested teachers in diverse areas. The latter is a necessary component of a project attached to a global satellite observation program. To facilitate this test, data from a geostationary satellite was used to cover the western half of the country.

Teachers and parents in 30 states were sent letters inviting them to participate. One in three responded. Of these, 8 out of 10 actually participated for a whole week at the end of April, 1997. Observations were reported either via the Internet or via e-mail (sometimes from the teacher's home or through their spouse's office). This level of connectivity is encouraging, since postal reports will require human intervention. The S'COOL website is designed to process e-mail and Internet reports automatically and thus enable large numbers to participate.

Throughout the week many constructive comments

were received from teachers and students, ranging from identification of typos or inconsistencies in a website that by now runs about 40 pages, to reports of their experience obtaining relative humidity according to the directions or converting units, to suggestions for a better way to configure the report form. Most of these comments resulted in a correction or change to the website. Based on observations from a high school near the Philadelphia airport, a discussion was also initiated of how to report the presence of contrails - a topic of much current interest by NASA researchers - which eventually led to a revision of the report form.

The teachers again reported a very successful experience. From 3rd grade teacher Sharon Moen in Brookings, South Dakota: "My students' involvement and interest level was higher than my expectation. They would not let me stop discussing this topic. They even wanted to miss lunch one day!" (Initially 4th grade was suggested to be a suitable minimum age for participants.) This class had an on-site advisor in the person of Dr. Madeleine Andrawis, professor at South Dakota State University and mother of one of the students. She reported: "It was a great week. The teacher was excellent, she taught the kids so many subjects related to the project. The kids loved it and learned so much." A front page article with color photo was printed in the Brookings Register. High school Earth Science teacher Roger Kennedy involved several teachers at his school outside Philadelphia. This was very successful: "It's really a shot in the arm for us to have our kids eager to do anything. They go outside with instruments in hand, subtracting wet bulb/dry bulb readings to figure out humidity, and trying to read our ancient barometer which has four scales on it. [... A learning disabled] science class is joining my fourth period earth science class when we go out. It's good for both sets of kids to see each other doing similar type of work. They take their "job" a little more seriously than most of my class; which serves as a motivational tool." One very small school (15 students in grades 1-12) in northern New York won a \$250 grant from a local TV weather station as a result of their participation.

2.5 Phase 3: International Testing

Given the school schedule in the US, a July phase was planned as a test of expansion over a large geographic area, particularly in the Southern Hemisphere and Equatorial region. A number of contacts were made, again mainly via personal networks, but the amount of time required to communicate with and get commitments from teachers in these regions was underestimated. Some of these contacts are still being pursued (and more are being sought). The material on the S'COOL website is also beginning to be translated into Spanish, French, and eventually German and other languages, in order to facilitate contacts in other regions.

2.6 Phase 4: Global Testing

Over the summer, work continued on developing additional pieces of the more automated S'COOL website, so that increased numbers of participants can be accommodated. These new elements - and the rest of the S'COOL website - will be given a workout Oct. 20-24, 1997 with a new set of teachers. At this writing (4 weeks beforehand) 12 teachers in the USA - including one university professor of science education - and 12 teachers in Europe are signed up to participate. More are anticipated. These teachers will receive draft copies of a new S'COOL brochure and S'COOL poster for their comment. The latter is intended to serve as a consistent cloud chart and also provide additional instructions for making observations. The teachers' suggestions will be incorporated into these materials so that they can be printed in time for the operational phase of the project.

Because of Daylight Savings Time, the NOAA-14 orbit has moved very late or even outside the school day in many locations. Geostationary satellite data will therefore again be used as a stand-in for CERES.

Rewards are also being developed for participating students: a S'COOL Cloud Observer logo has been developed, and will be provided to the students in decal form as soon as possible. Other incentives and rewards for both students and teachers may be developed, based on what the teachers suggest is most useful. In addition, a S'COOL "Wall of Fame" has been placed in the NASA Langley Atmospheric Science Division. The intention is to keep CERES researchers informed about the project, and to facilitate school visits by NASA researchers when they are in the vicinity of a participating school.

Since the S'COOL website is now quite automated, efforts to attract more participants have increased. Articles will be placed in National Science Teachers Association publications, in the magazine of the International Baccalaureate Schools, and in other publications. Brochures are being made available at a variety of education fairs and teacher conferences.

2.7 Phase 5: TRMM Satellite Testing

The TRMM satellite is set to launch in November, 1997, from the Tanegashima space center in Japan. It will be in orbit for about three months before it begins returning data on an operational basis. Phase 5 will be the final development phase for S'COOL. Held in January 1998, it will test - and familiarize participating teachers with - the orbital characteristics of the TRMM orbit. At a 35 degree inclination, this satellite will have a ground track that drifts around the globe over a 16 day period. This means it will have periods when it sees a given area only at night; and also that it can't see beyond about 35-40 degrees north or south latitude. For these reasons, participants during this time will be given a choice of using either the TRMM or the NOAA-14 spacecraft. Launch of the EOS-AM spacecraft into a polar

orbit in mid-1998 will alleviate this problem later in the year, but still require an interface capable of handling two satellites.

3. OPERATIONAL CONFIGURATION

The operational phase of the S'COOL project begins after successful completion of Phase 5 in January 1998 and continues for a number of years thereafter. The scheduled duration of the CERES experiment is 15 years. During the operational phase the S'COOL website will be as automated as possible. As a result, teachers can participate at a time and for a duration which best fits their particular curriculum and the level and interest of their students. In spite of this, the S'COOL project will continue to be dynamic, with occasional additions of information to the website and continuing development of other materials. This may eventually include teacher or student workshops and other activities.

There are five main elements of the Operational Configuration of the CERES S'COOL Project, described below.

3.1 Registration

Interested teachers can register to participate via e-mail, mail, fax, or telephone (contact information below). We request the teacher and school name, school address, grade level, postal and e-mail (if available) address, whether or not Internet access is available, and the location (city, state and country, as well as latitude and longitude, if known). Upon registration teachers will be given a login ID and sent a set of materials. There is no participation fee.

3.2. Overpass Determination

When ready to start observing, the teacher or a student will access the S'COOL website and fill in a form with start and stop dates, along with their latitude and longitude and the offset from GMT to local time. Information to help them determine these values is available on the website. Overpass times for their location will be returned. Those without Internet access can request overpass times via E-mail, mail, fax or phone. From the list, which will typically include several choices each day, a teacher can select an overpass that best fits their class schedule.

3.3 Observe and Record Cloud and Surface Properties

Both the S'COOL poster and the website offer a concise explanation and description of the things the students need to observe and record, as well as instructions and tips for doing so. All observations can be made with materials on-hand in the classroom, though a set of weather instruments is useful.

3.4 Transmit Results to NASA

The results can be reported to NASA via the Internet form, e-mail (a template should be used to facilitate automatic processing), mail or fax. They will then be placed in a database which is accessible via the Internet.

3.5 Compare to Satellite Observations

Once CERES is providing data on a routine basis, results matching participating S'COOL locations will be stripped, averaged, and placed in an Internet database. Minimal AVHRR and GOES data from the development phase is currently available. The satellite and surface databases can be queried over the Internet via a single interface. Entries matching in latitude/longitude and/or a time interval can be retrieved, as can searches on a few other items. The results are displayed on a web page, and will eventually also be available in a downloadable spreadsheet form for further examination by the students. For those who don't have Internet access, results can also be obtained by written request to the DAAC. It is hoped that creative students will learn many interesting things from these comparisons, and that they may even bring new knowledge and ideas to the CERES scientists. Validation of a global dataset is limited by the data and the people available to study it. The S'COOL project has the potential to be an important contributor to both.

The S'COOL data will also be available to the CERES Science Team and the atmospheric science research community as a whole. At a minimum, they may find the clear sky observations from S'COOL very valuable in their validation efforts. Other uses of the data, such as estimating cloud base, are also possible.

4. S'COOL OPPORTUNITIES

The CERES S'COOL project is now available to all interested teachers. Registration information should be sent to NASA Langley (see contact information below). Starting in 1998 teachers can participate at their convenience, when it best fits into their curriculum.

5. REFERENCES

1. <http://asd-www.larc.nasa.gov/SCOOL/>

6. CONTACT INFORMATION

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